ELEMENTS OF

EARTH BORING

FOR WATER

(ILLUSTRATED)

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FIRST EDITION

PRINTED AT THE COMMERCIAL PRESS, MADRAS, S. E.

1917

Price One Rupee,]

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TO

W. HUTTON, Esq., A. M. I. C. E.,

Superintending Engineer, P. W. D.

Sanitary Engineer to Government, Madras.

PREFACE.

As indicated by its title and bulk, this work is not meant to be an exhaustive treatise on the subject of Earth Boring. My interest in the subject was aroused when I had charge of boring operations in connection with town water supply schemes in the Madras Presidency for about five years. At the end of this period the nature of my duties changed.

I have taken advantage of the experience gained by me in writing, as time permitted, this hand-book dealing with the subject of Earth Boring in a simple way embodying in it freely my own experience.

I hope that the information contained therein will be of some practical value to my brethren who may be afield engaged in boring operations and others interested in the subject.

Triplicane,
Madras, S. E.
February, 1917.

K. NARAYANA IYENGAR.

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ELEMENTS OF

Earth Boring for Water.

PRELIMINARY.

1. Earth-boring is the art of piercing or making a hole in the ground.

2. The object may be varied, *viz.*, to find out the nature of different soils underlying the ground surface, to find the level and quality of water below ground, to tap springs of water, oil, etc., situated at comparatively great depths below ground, and so on.

3. My readers have doubtless observed, even casually, the sides of railway cuttings, quarries, gravel pits, excavations for wells, etc. They will remember that the nature of soil below ground in them is not generally the same to any great depth. Below the surface soil which is usually covered with vegetation, they might have observed in some cases successive layers of sand, gravel, loose rock, hard rock, etc., and in other cases alternate layers of sand, clay, kunker etc., overlying rocks of different degrees of hardness if this last is not buried very deep below the ground surface.

4. A little knowledge of Geology will show that the earth is made up of different strata or beds of soil and a

study of an elementary hand book on geology* is a good help to those engaged in boring work.

5. A knowledge of the different kinds of strata underlying the ground surface (subsoil strata) and the level of water below ground (subsoil water level) is necessary for various purposes: a railway engineer should have an idea of what soils he may have to cut through in taking his line in order to enable him to estimate the cost of his proposed work; those who are engaged in prospecting water supply should know, as a preliminary to other works, if there are soils below ground containing water, if so whether water flows through their interstices freely or otherwise; and so on.

6. *Advantages of Boring.*—Such preliminary enquiries may be conducted by borings which have many advantages over putting down actual pits (technically termed *trial pits.*)

(1) In pits damage to existing ground and property is entailed as the pit or excavation occupies comparatively a very large area of ground surface; a bore-hole of say 4-inch diameter will suffice in such cases.

(2) While a pit can be dug to a limited depth only owing to difficulty and cost of excavating, a borehole can be sunk, with compartively very

* Professor Geikie's Geology Primer, Science Primer Series, priced at one shilling, will do.

much less labour and cost, to about 10 to 12 times the depth of a pit.

(3) Examination by actual excavation should cease when springs are met with, while a borehole may be continued far below the level of springs without baling out water at all.

7. There are, however, certain objections to accept the results obtained by borings; but as the advantages offered by them outweigh the disadvantages, and as boring is an effective method *provided it is managed with care and skill*, the art plays an important part in the economy of various callings.

BORING TOOLS AND PLANT, THEIR USES, ETC.

8. With the foregoing preliminary remarks, we may proceed to a study of the different methods of boring on a small scale. Let us first familiarise ourselves with the tools and plant used in the operation and their use. Figures 1 to 22 illustrate a set of tools and plant most commonly used, and the same manufactured by different makers vary slightly in form, but all are intended to effect the same purpose. The table below gives a description of the tools etc. Use of each tool, etc., given in the last column of the table will be understood more clearly when the boring operations are described in the succeeding paragraphs.

9. TABLE.

Serial No.	Fig. No.	Description of tool or plant.	Quantity required.		Use of tool or plant.
		TOOLS.			
1	1	Open (clay) auger ...	No.	1	To bore through and bring up clay or similar stiff soil.
2	2	Worm auger ...	,,	1	To loosen soil which is too stiff for clay auger.
3	3	Nose shell auger ...	,,	3	To bore through and bring up loose stuff, such as sand &c.
4	4	Flat chisel ...	,,	1	To loosen and pound hard stuff.
5	5	V ,, ...	,,	1	do. harder do.
		APPLIANCES AND PLANT.			
6	6	Hand dogs ...	,,	4	For raising and lowering rods and tools and holding them on the borehole when making or unmaking the joints between them: hand dogs also to fasten and unfasten the screw joints between rods and tools.
7	7	Lifting dog (two types *a* and *b*) ...	,,	1	
8	8	Tiller rods with screws, complete...	Set	1	To serve as a lever in working the tools.

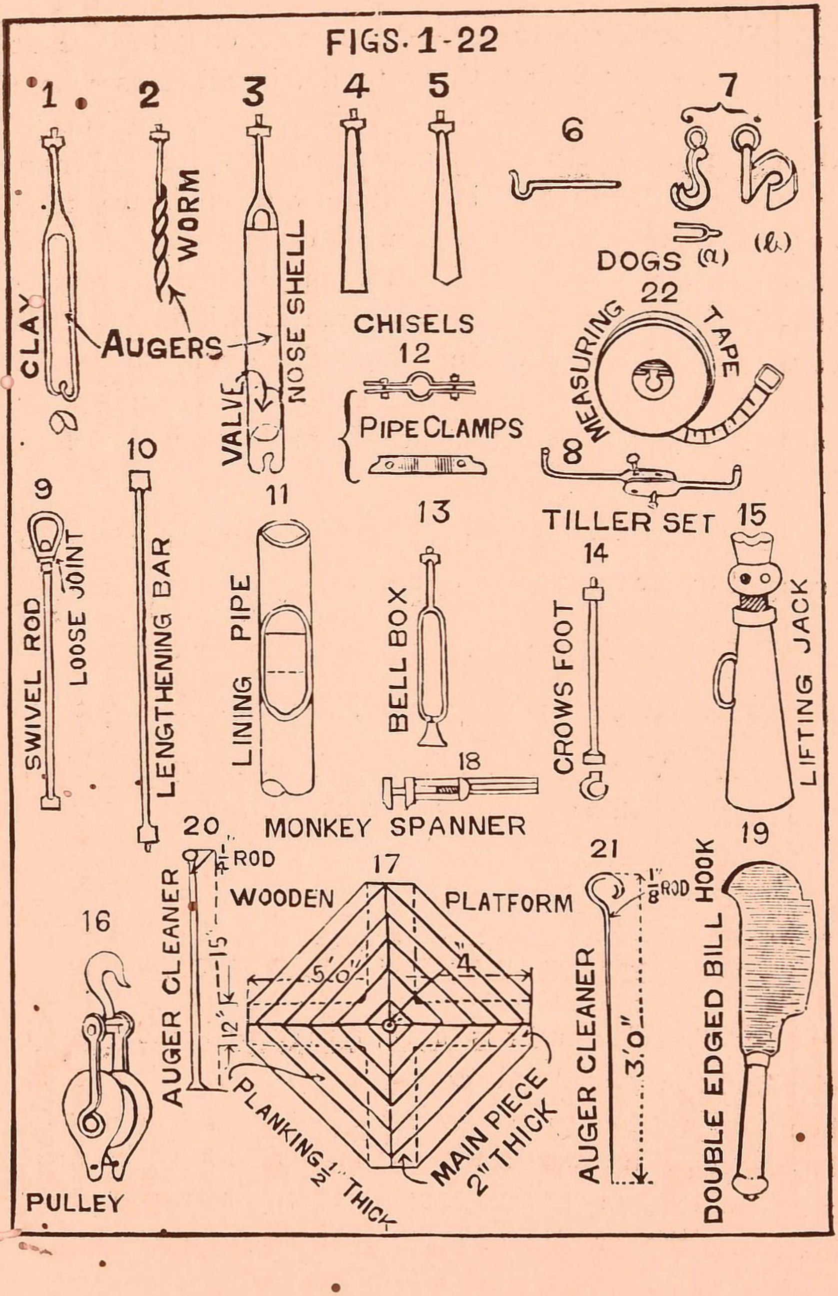
9	9	Short swivel rod ...	No.	1	To form the topmost one of lengthening bars allowing rope attachment and turning of rods when working.
10	10	Lengthening rods, 10 ft. long each and 1 to $1\frac{1}{2}$ inches square.	,,	5 or more	To make rigid connection between the boring tool at bottom of borehole and the topmost rod.
11	10	Do 5 ft. long do. ...	,,	1	
12	11	Lining pipes 3 inches internal diameter and upwards and $\frac{1}{4}$ inch thick; screw joints flush inside and outside.	50 to 60 feet total length		To line the borehole to prevent its sides collapsing.
13	12	Pipe clamps or rests (long type).	Sets	2	For various uses described later on.
14	13	Bell screw or bell box ..	No.	1	To recover rods or tools accidentally dropping into, or remaining in, the borehole.
15	14	Crow's foot ...	,,	1	
16	15	Four ton lifting bottle jacks wrought iron cylinder.	,,	2	To pull up lining pipes or augers which have stuck fast in the borehole.
17	16	Iron pulley ...	,,	1	For tripod top.
18	17	Wooden platform* ...	,,	1	For men to stand on and work.
19	...	Casuarina or similar poles, 25 to 30 feet long.	,,	3	For making a tripod or derrik.

* This can be made locally by jointing two main pieces of good planks at right angles to each other with a hole cut out in the centre, and nailing thinner cross planks over these in each of the four quadrants as shown in the figure.

TABLE—*contd.*

Serial No.	Fig. No.	Description of tool or plant.	Quantity required.		Use of tool or plant.
20	...	Manilla rope coils, 50 feet long and 3 inches in circumference.	No.	2	For jumping tools and other purposes.
21	18	Monkey spanner 12″ size ..	,,	1	For tightening nuts, &c.
22	18	Do 10″ ,, ...	,,	1	For tightening nuts, &c.
23	...	Mammooti ...	,,	1	For miscellaneous purposes.
24	...	Crowbars, each 5 ft. long ..	,,	2	For miscellaneous purposes.
25	19	Double-edged bill book ...	,,	1	For miscellaneous purposes.
26	20	Clay auger cleaner ...	,,	1	To take out soil brought up by the clay auger.
27	21	Nose shell auger clearer ...	,,	1	do. nose shell auger.
28	22	Measuring tape, 100 ft. long ..	,,	1	To take measurements.
29	...	Wooden sleepers or heavy scantlings, each 9 to 10 feet long.	,,	2	To lay across the top of pit.

10. In addition to the above, about five viss of spare coir rope and about one viss of crude castor or other suitable lubricating oil should always accompany the tools when taking them out to the field for boring work so that there may be no suspension of the work with consequent loss of time and money for want of these sundry materials.


FIGS. 1-22
1
2
3
4
5
6
7
WORM
CLAY
AUGERS
NOSE SHELL
VALVE
CHISELS
DOGS (a) (b)
22
MEASURING TAPE
12
PIPE CLAMPS
8
TILLER SET
9
SWIVEL ROD
LOOSE JOINT
10
LENGTHENING BAR
11
LINING PIPE
13
BELL BOX
14
CROWS FOOT
15
LIFTING JACK
18
MONKEY SPANNER
20
AUGER CLEANER
1/4" ROD
15"
12"
17
WOODEN PLATFORM
5'0"
4'
PLANKING 1/2" THICK
MAIN PIECE 2" THICK
21
1/8" ROD
AUGER CLEANER
3'0"
19
DOUBLE EDGED BILL HOOK
16
PULLEY

11. *Preliminary Pit.*—In commencing to bore at any given spot the first thing to do, in all cases where it is possible, is to sink a pit 7 feet square and about 8 feet deep. The borehole may then be commenced from its bottom. The pit will facilitate work and save time in the progress of boring. In all cases the bottom of the pit should be kept six to nine inches above the subsoil water level when the same is within ten feet of the ground surface. In cases where this pit is not possible owing to high level of subsoil water and other causes, boring may commence from the ground surface itself.

12. *Soils.*—For boring purposes soils may be grouped under three main classes:

I. Stiff soils, e.g. clay, loam, kunker &c.

II. Loose soils, e.g. sand, gravel, pebbles, silt &c.

III. Very stiff and hard soils, e.g. very stiff clay, different kinds of rock &c.

I. BORING THROUGH STIFF SOILS.

13. The clay auger is taken, its screw threads at top oiled and the swivel rod screwed on to it. A tiller set is then fastened on to the swivel rod to form a lever, and the auger with these attachments is held upright in a small hole made by jumping a crow bar two or three times into the ground or bottom of pit, from whichever

point boring is commenced. Steadying the whole plant and holding it quite plumb until it sinks a few feet, a rotary motion is given to the plant *in the direction of the hands of a clock* (never the opposite way), applying a downward pressure on the tillers during rotation. The auger sinks into the ground piercing a hole and collecting the soil in the longitudinal slit of the tool. When the auger has sunk to a sufficient depth, equal to the length of its slit as a maximum, the whole thing is lifted up, and the soil collected in the slit scooped out by the clay auger cleaner (Fig. 20).

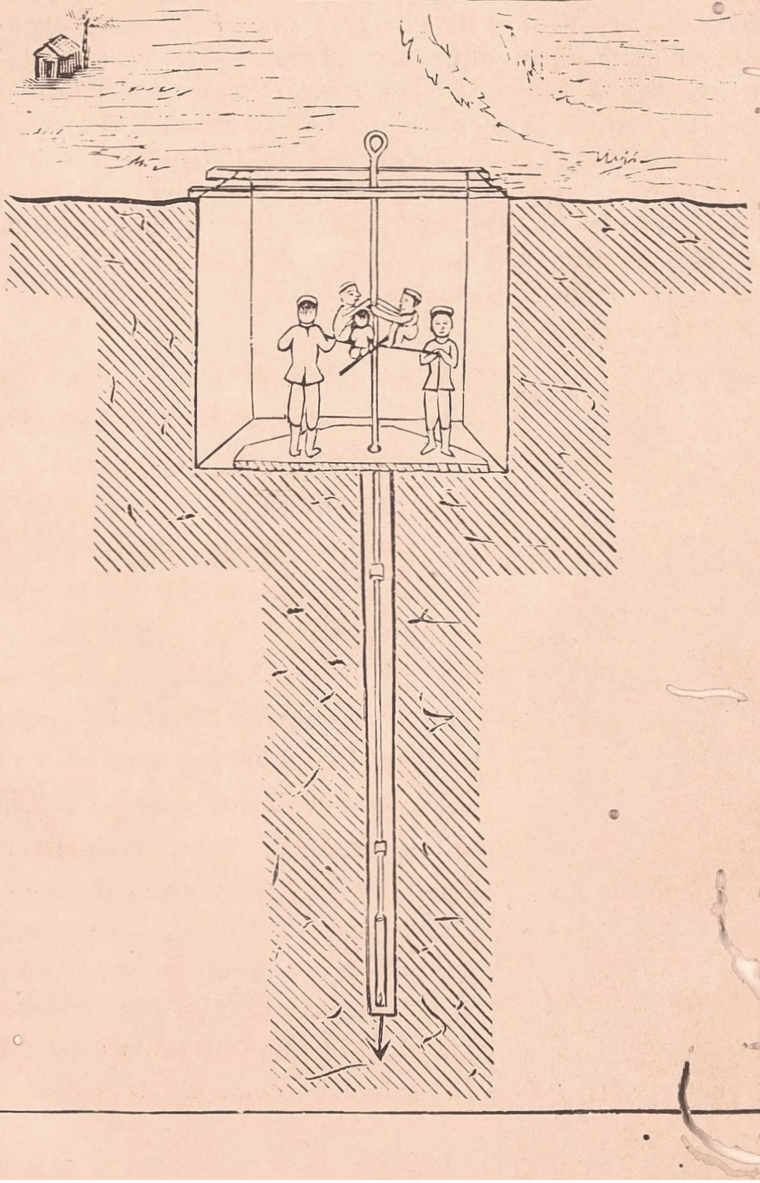
The whole operation is repeated over and over again.

14. When about three feet has been bored, two men can seat themselves on the tiller rods to exert a downward pressure on the boring tool, and additional pressure may, if necessary, be given by attaching two hand dogs to the lengthening rod over the tillers in a direction at right angles to the same, and two more men seating themselves on the hand dogs. The wooden platform may, at this stage, also be placed with its central aperture directly over the borehole. This will facilitate the work.

The general arrangement of the operation described above is illustrated in fig. 23.

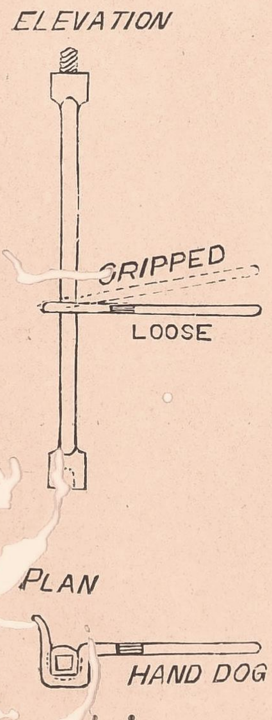
FIG. 23.

BORING IN STIFF SOIL.



15. *Lowering and raising of tools and rods into and out of borehole.*—At first the rod and tool may be lowered into and lifted out of the borehole by means of the tiller rods. When one or more lengthening bars are screwed on as the boring gets deeper, they should be lifted up and lowered by hand dogs and lifting dog. In using the lifting dog a tripod with pulley should first be erected over the spot of borehole as will be described later and the lifting dog tied on to one end of the rope, or attached to a spring hook which is sometimes used. When the mouth of the lifting dog is let into the square shaft of the lengthening rod and drawn up, the dog catches the rod at the head of the latter which can then be raised or lowered as desired.

FIG. 24

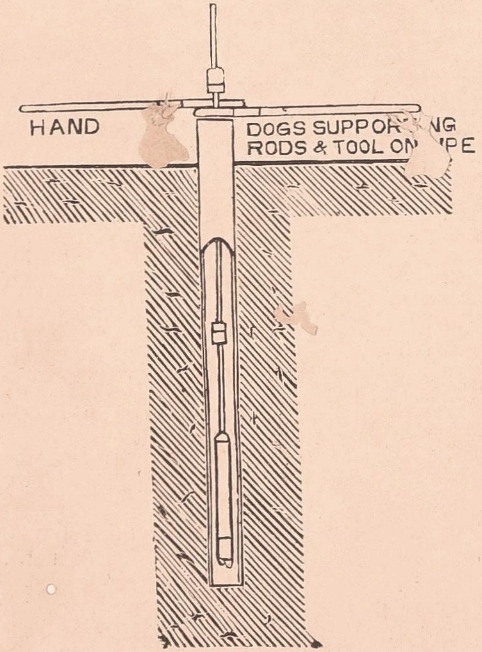


They are, however, the hand dogs which are more useful and the operation of raising and lowering rods may be carried out with these alone when the borehole is not very deep. The mouth of the hand dog can be slided into the square shaft of the lengthening bar or tool holding the dog horizontal as shown in fig 24. In this position the hand dog can be freely slided up or down along the shaft of lengthening bar. When the hand dog is held slightly inclined as shown by dotted lines, it *catches* the rod which can then be bodily raised from, or lowered into, the borehole. Keeping in mind the above facts the operation of lowering or raising the

rods &c. by two or four men each using a hand dog can be easily understood. In changing the hand dogs from one point to another on the rod, let them not be taken out but be simply slided down or up with the hand dog held horizontal. It is important to bear in mind that when one man is sliding the hand dog, the other man holds his hand dog inclined; if both the men attempt to slide their hand dogs simultaneously the string of rods and tool will slide down with a great force and may cause damage to the pipes &c. or injury to the workmen.

The string of rods and tools can be rested on the top of borehole or borepipe as shown in fig. 25 which is necessary when screwing or unscrewing rods and tools.

FIG. 25

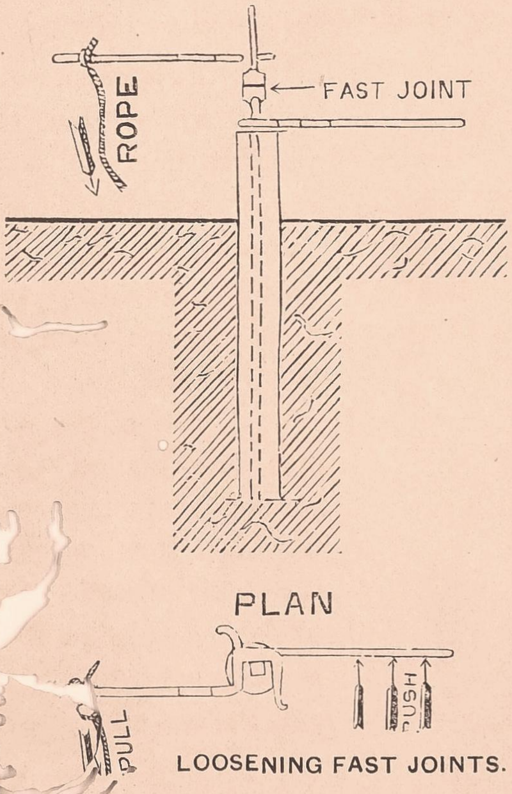


16. *Fast joints.*—It will be noticed that, in working the stiff soil auger, the string of tool and rods is continually turned clockwise to force down the auger into the stiff soil. In this operation we are also screwing in the several joints between rods &c. fast. When the tool which has worked a trip in the borehole has to be taken out, the several rods, as

each comes up, should be unscrewed by leverage which exerts some force. In unscrewing the rods two hand dogs may be slipped—one to each of the adjacent rods to be unscrewed, and the rod unscrewed by applying a turning force at the ends of the hand dogs which act as levers. It sometimes happens that the joints are too fast to be unscrewed thus. The easiest way to unfasten the joint in this case is to sling the manilla rope on to the end of one of the hand dogs and to pull the rope at a point a few feet away from the hand dog as shown in fig 26.

FIG. 26.

ELEVATION.



LOOSENING FAST JOINTS.

The joint yields under this method in nine cases out of ten.

17. The borehole need not be lined in this class of soils unless it is necessary to preserve it for sometime, say a fortnight or longer. The method of lining will be described under soils of class II below.

II. BORING THROUGH LOOSE SOILS.

18. In this class of soils the borehole will not stand by itself owing to the inability of the soil to maintain vertical sides even for a short period. Hence the borehole has to be *lined* which is done by sinking wrought iron or steel tubes as the boring proceeds.

19. *A tripod* made of three casuarina or other poles is raised over the spot proposed for borehole and the iron pulley suspended at its top with the manilla rope slung over the same, and the swivel rod attached to one end of the rope.

20. The poles forming the tripod should be about 25 to 30 feet long if a convenient height of tripod is to be formed to suit all localities. Any length less than 20 feet is useless.

21. Having raised the tripod, a lining tube with cutting edge* at bottom is taken, a pair of pipe clamps attached at about 7 feet from the bottom or cutting edge and the pipe with clamp held upright on the spot. If possible, it is stayed by burying a short length, say two feet, into the ground or bottom of pit. Then the swivel rod at one end of the rope over the pulley is screwed on to a nose shell auger and both of these lowered into the pipe *slowly*. If the length of the swivel rod be found insufficient, one of the ten feet lengthening rods may be used, or the rope itself may be let down into the pipe, the use of lengthening bars not being essential except to add to the weight when required. When the shell auger reaches the bottom of the borehole, it is worked up and down

* It is preferable to use a tube with cutting or sharp edge for the first pipe to be sunk in a boring. If a tube with cutting edge be not available, it does not much matter.

continuously by men who hold the other end of the rope. In this operation the sand or loose material gets into the socket of the nose shell auger and fills it as the valve at the bottom of the tool (see fig. 3) prevents the soil from falling down again. As jumping goes on, the lining pipe sinks down of itself in the first stages of boring thus clearing a hole through the loose soil.

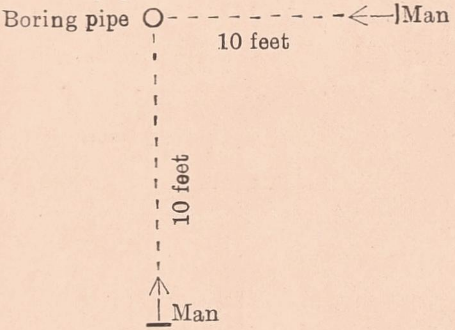
22. When the nose shell auger is filled with sand (generally indicated by the lining tube not sinking further when the tool is worked) it is hauled up, detached from the rods and taken aside to empty the contents. A second shell auger is immediately attached to the end of swivel rod and the operation is repeated to continue the borehole deeper. Two nose shell augers are thus worked on alternate trips.

23. *In emptying the contents* the nose shell auger is held valve end upwards, a little water poured in through the valve end and the contents pricked from below (not through the valve) with the nose shell cleaner (fig. 21) until they run out. In cases where the contained soil sticks fast in the auger, the tool may be jumped three or four times on a log of wood to enable the contents to run out ; but this practice should not be resorted to if pricking as described above is found sufficient.

24. *Water necessary.*—When the nose shell auger is worked, scarcely any of the loose soil is found to enter its socket if the soil is not freely mixed with water. Hence in cases where sub-soil water is not reached near the bottom of the pit, a quantity of water (an ordinary potful [illegible] do) should be added to the borehole before commen- [illegible] work the auger each time.

VERTICALITY OF LINING PIPES.

25. It is of the utmost importance that the lining pipes should be sunk quite vertical; hence care should be taken to see that the pipe is held plumb until it sinks about five feet. Verticality may be tested by a plumb-bob. I have found the following ready method effective in the work done by me. Two men stand facing the pipe at distance of about ten feet from the same and along two lines at right angles to the pipe thus:—



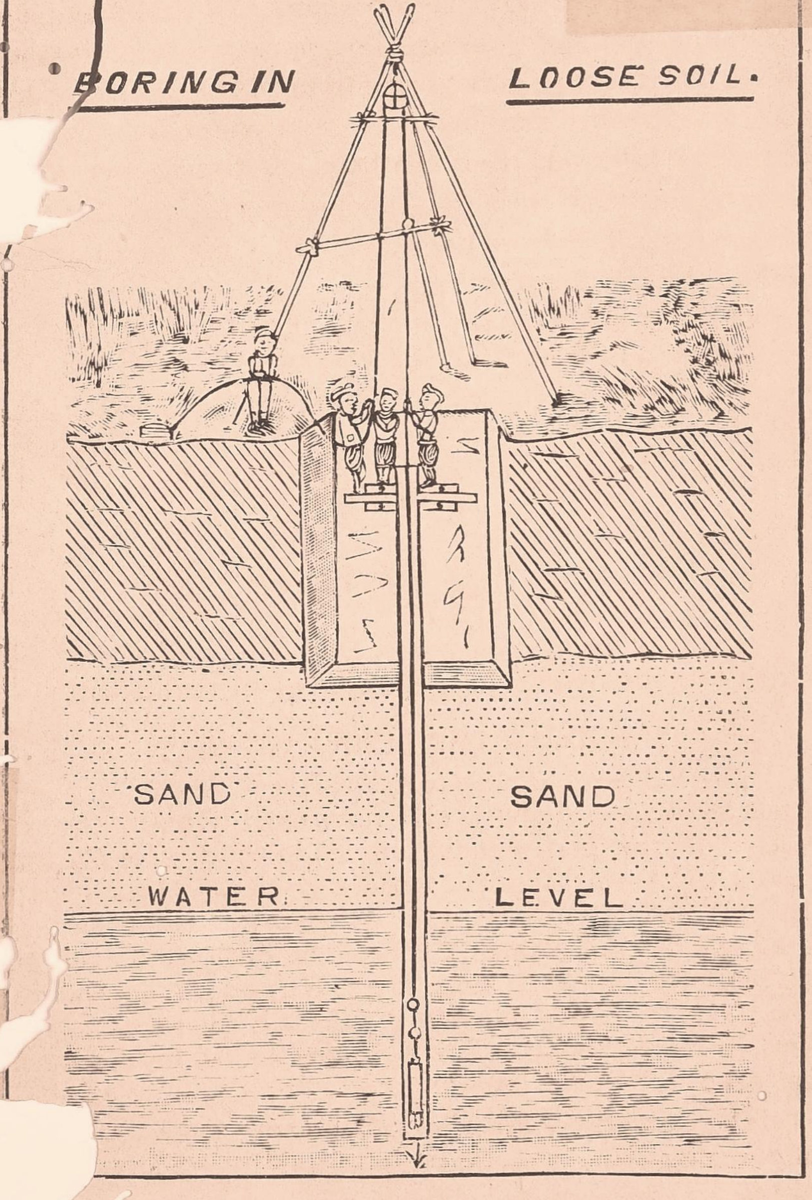
Each of the two men will then carefully watch and direct the men who hold the pipe as to its verticality.

SINKING THE LINING TUBES.

26. When the lining tube has been sunk to about 5 feet as described above, it is sufficiently firm, in general, to be sunk further without any support to preserve its verticality. At this stage the wooden platform is slided down the pipe and fixed on the same at a convenient height between two pairs of clamps. Some of the men then stand on the platform and work from there. The additional weight now brought on the pipes will generally be found sufficient to cause them to sink of themselves till about fifteen feet deep.

The operations described above are generally illustrated in fig. 27.

FIG 27



27. When it is found that the lining pipes do not sink of themselves when the shell auger is worked, a rotary motion, *in clockwise direction* (on no account anti-clockwise), should be given to the lining pipe as the nose shell auger is worked. This rotary motion may have given by means of two levers formed by letting in two crowbars at opposite ends into the open spaces between a pair of clamps fixed to the pipe. The rotary motion does not in practice injure the screw threads of pipes when boring to moderate depths, say 100 feet.

28. As each pipe sinks nearly to its top, a fresh length of pipe is screwed on, care being taken to see that the screw threads are first cleaned and oiled and that the pipe is screwed down with an easy turning. If any resistance is felt, better unscrew the pipe and screw on again properly; never use force.

29. When the pipe has sunk about 35 feet, additional weight has to be put on the platform which may be done by loading the platform either with sand bags or with some heavy iron materials lying on the works.

30. In driving the pipes down, only weighting and rotating methods as described above should be used, and *on no account* should the pipes be hammered at their tops, even by placing a cap or wooden log &c. to serve as a cushion. Hammering at top will only result in injuring the top of pipe and the screw threads thereon, with the result that the succeeding pipe cannot be screwed on it. In deep borings special methods of *pressing* the

down are employed, but a description of those methods is beyond the scope of this manual.

STICK-FASTS; THEIR PREVENTION AND REMEDY.

31. There is one important point to be very careful about in working the nose shell auger, and that is to avoid "stick-fasts." The nose shell auger should never be allowed to rest *even for a few seconds* at the bottom of the borehole; else the inrushing sand and grit under the force of sub-soil springs, when working in loose or running sand, gets into the annular space between the lining pipe and the shell auger and jams the tool fast in the pipe. As soon as the shell is full of sand, or if it be found necessary to stop jumping for a short time when the auger is in the borehole, the tool should be hauled up, say ten or fifteen feet, and there allowed to rest in the borehole. It may then, at leisure, be taken out to empty the contents, or let down again for further jumping.

32. If in spite of precaution a stick-fast should occur (it invariably does until the workmen experience it themselves once or twice) it is useless to try to extract the tool by merely pulling it up without the aid of jacks: no recourse whatever should be taken to such practices as turning the rods in the hope of loosening the tool and pulling it up, which will only make matters worse. One very simple way to tackle the situation is to raise the lining pipes bodily (see article 39) about 6 inches at a time to about two feet and keep on giving an upward jerk to the tool and rods by means of the rope. The

sand or grit jamming the tool sinks down in this operation and the tool is set free to be drawn up.

BORING THROUGH ALTERNATE STRATA OF STIFF AND LOOSE SOILS.

33. Where alternate strata of sand and clay have to be bored through, a combination of the two methods described till now should be used. In this case, the lining pipes should be sunk through the clay also to reach the underlying sand. In sinking pipes through strata of clay, it is not necessary to sink them simultaneously with the working of the clay auger as in the case of sandy strata. A few feet may be bored and then the pipes sunk by rotating or pressing. In some cases the pipes sink of themselves as the boring proceeds.

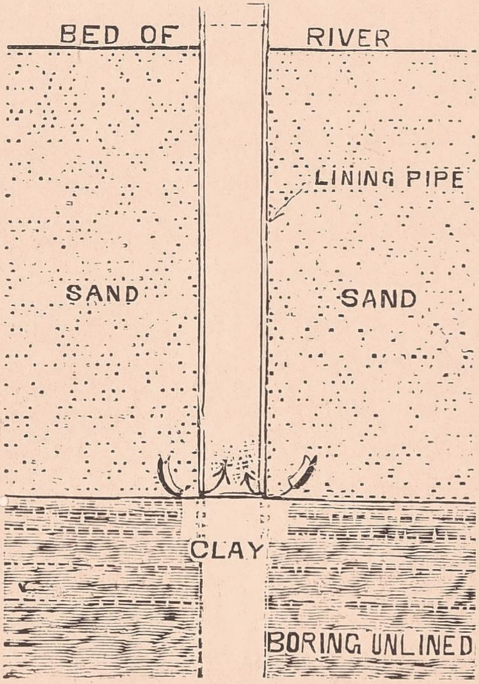
34. As examples of the previous paragraph we may briefly consider two cases :—

(i) Suppose a boring has to be made at a site where there is 15 feet of clay from the ground surface below which there is sand. The boring will be commenced with the stiff soil auger as described in paragraph 13 and when the boring reaches 15 feet, the clay auger brings up some sand indicating that sand bed has been reached. Now lining pipes should be sunk through the full depth of clay stratum. Then the nose shell auger should be worked with the simultaneous sinking of pipes as described for soils of class II.

(ii) Suppose a boring has to be made at a site where there is 15 feet of sand from the surface below which

there is clay for instance, in a river bed. Boring is here commenced with the nose shell auger, lining the hole simultaneously. When 15 feet has been bored through, the nose shell auger will come up with some clay sticking [illegible] bottom and choking its valve, indicating that clay has been reached which should be bored through with [illegible] clay auger. Before doing so, the lining pipe should be sunk well so as to bed it 6 or 12 inches in the clay as shown by dotted lines in fig. 28; otherwise sand will keep

Fig. 28.



on running into the borehole through the space between the bottom of pipe and the top of clay as shown by

arrows in the figure and prevent the clay auger reaching the clay bed.

III. BORING THROUGH VERY STIFF AND HARD SOILS.

35. In this case the soil does not yield either to clay or nose shell auger. It should first be loosened

(1) by working the worm auger just in the same manner as the clay auger and then bringing up the loosened material (if it does not come up stuck in the spirals of the tool itself) by working the clay auger, or,

(2) by jumping the flat or V chisel according to the hardness of the soil and bringing up the loosened or broken material by using the nose shell auger. At every jump of the chisel it should be slightly turned so that it may not cut through the soil along a single line only but break or pound it all round.

Note :—In describing the method of jumping the nose shell auger it was remarked that it is not essential to use the lengthening bars and that the rope itself may be let down into the boring. In jumping the chisels, however, it is advisable to use the lengthening bars so as to increase the force of blow on the hard stuff. The point of chisel is sometimes made of T shape also when it is called a T chisel which is recommended for hard rocks.

36. The method described under this heading is for boring in moderately hard soils, and not in *solid rock* such as compact gneiss or granite. The latter rocks require special drills worked generally by mechanical

power. The scope of this volume does not include a description of these nor boring in hard rocks is necessary except under special circumstances for which specially trained and experienced agency should be employed.

RECOVERING TOOLS FROM BOREHOLE.

37. Accidents in boring work are generally unavoidable though the chances are few in boring to shallow depths which we have been considering till now. When tools or rods accidentally drop into, or remain in, the borehole they may be recovered as follows:—

(i) If the screw head is left on, the bell box is let in by means of lengthening rods and an attempt made to screw on the same to the top end of the rod or tool. When screwed on the whole thing may be hauled up.

(ii) If the screw end has broken off then the crow's foot is let in, the rod or tool caught by the same and the whole hauled up.

38. In bad cases of accident it sometimes happens that the boring should be given up and a fresh one sunk near it. This may prove cheaper too.

PULLING OUT LINING PIPES.

39. When it is found necessary to pull out the lining ...ms from a borehole the following methods may be ...ployed :

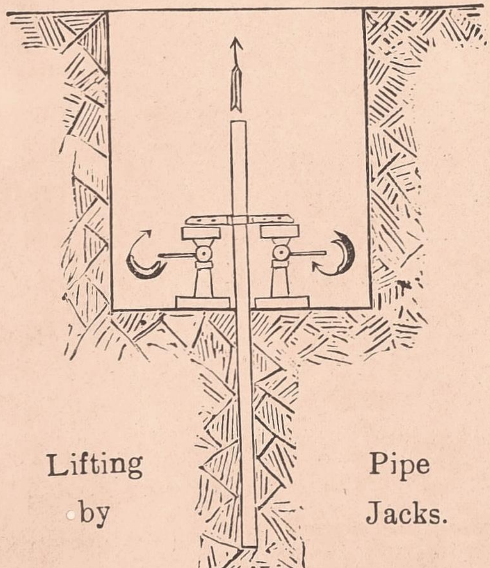
(1) If it is immediately after a borehole is sunk, the ...ing pipes will still be loose. The manilla rope from ...ver the pulley block may be fastened to the underside of

the clamp fastened on the pipe, and the pipes hauled up by simply pulling the rope at the other end. As each joint between two consecutive pipes comes up a clamp should be fixed on to the lower pipe and rested on two sleepers, and the top pipe unscrewed and taken up. The rest of the pipes are pulled out by repeating the proc

(2) If the pipes have stuck fast not yielding to above process, the clamps should be fixed to the pipe near the ground or bottom of pit (if there is one) level and the pipes levered up by letting in crowbars under the long arms of the clamp. After the pipes have been lifted up to some height by this process they will be loose enough to be pulled out further by the process detailed under (1).

(3) If the pipes have stuck too fast even for being levered up by crow-bars, they should be lifted up to some height, until they are loose enough, by *lifting jacks* (see fig. 15). Two jacks are placed, one under each arm of the pipe clam, shown in fig. pip their screw en turned, car taken to see lin are turned equa o

Fig. 29.



Lifting by Pipe Jacks.

simultaneously. A single jack should not be used for the purpose, as thereby the top pipe gets inclined to one side when the lower one is held fast in the ground. The effect will be that the top pipe splits along the joint at its lower end, and comes up by itself leaving the other pipes in the ground. If the latter are buried deep, especially below subsoil water level, they cannot be taken out at any reasonable cost.

CARE OF TOOLS AND PLANT.

40. In the foregoing paragraphs I have described the method of making borings on a small scale intended for the use of beginners in the work. They should, in addition, exercise care in the preservation of tools &c in good condition which is none the less essential to the efficient and quick progress of the work as well as to minimise the recurring expenditure on the comparatively costly materials. The screw threads of the tools, rods, pipes &c, should always be kept oiled and not allowed to rust, nor carelessly kept scattered about on the works. The oiled screw threads should, as far as possible, be kept clean and free of earth &c. When storing or sending them elsewhere, the oiled screw threads should be carefully wrapped in gunny.

41. The valves of nose shell augers get damaged at intervals depending on the extent to which they are used. Of the three tools mentioned under item 3 of table in paragraph 9, one should always be kept as a reserve *on the works* and the other two used alternately as described

already. The damaged one should be *at once* repaired. This can be done even in out-of-the-way places if a spare piece of good leather, which is often difficult to obtain even in small municipal towns, be kept on hand with the tools. Negligence to keep a reserve tool *on the spot* does invariably lead to loss of time and money.

COST OF BORING.

42. *Cost of tools and plant.*—The cost of a set of boring tools and plant depends on the size of the same, the size and number of tools varying with the depth to be bored. The cost of a set suitable for boring up to 100 feet including necessary lining pipes and materials which can be made or procured locally—*i.e.*, the complete set included in the list in paragraph 9—will be about Rs. 1,000 under normal conditions of market price. It is more economical ultimately to go in for a first class set made of properly tempered steel cutting edges &c., in one of the well known firms than to go in for a cheaper set. Well known firms in India now quote for and supply sets suitable for boring to different depths.

43. *Cost of sinking.* The cost of making a boring is generally worked out and stated at so much per foot depth. There are various local conditions and circumstances determining the above rate and the following are some of the chief items:—

(*a*) Depth of boring. The cost per foot in the first depths is low, but increases rapidly as we go down deeper. The average rate per foot may,

therefore, work out higher in deep borings than in shallow ones.

(*b*) Nature of soil. In comparatively soft and yielding soils, progress of boring is quick; but is disproportionately slow in rock. Hence the cost per foot average is very much higher in the latter case.

(*c*) Labour conditions. Where labour is cheap or where skilled labour is available the cost will be proportionately less.

(*d*) Number of borings. When a single boring to a shallow depth is to be sunk in an isolated spot, the cost will be rather high as materials &c., have to be carried to the site for one boring and *all* charges debited against the same. On the other hand if a series of shallow borings have to be taken in a limited area, the cost per foot will be surprisingly small.

44. *Two set system.* In this connection I would like to refer to a system which I have practically found to work effectively in regard to the rate of progress, and in point of cheapness too would compete with similar work done elsewhere. At first I employed on the work, as usual, a set of coolies numbering from 4 to 10 according to the depth to be bored, and the men would work, according to the general usage, 8 hours a day, partly in the forenoon and partly in the afternoon. I found that the progress was not as quick as I wished owing to the following reasons.

(i) There would be break of work for a few hours between the forenoon and the afternoon shifts, and a good part of time in the afternoon would be wasted in restarting the work, in removing the stuff deposited in the borehole in the interval, &c.,

(ii) The men could not exert much when handling the tools both morning and evening. Thus there would be effective work of about 4 hours only for the working day.

Then I increased the number of working hours per day to twelve—6 A.M. to 6 P.M.—and put on two sets of men each set to work 6 hours a day—6 A. M. to 12 Noon or 12 Noon to 6 P. M. The rate of progress of boring was then three to four times the previous rate with the consequent decrease in cost also per foot. Wherever preliminary pits were possible the men, in addition to working at boring for 6 hours a day, had to sink pits in advance for other borings working an hour or so a day in the cool hours of the morning or evening. This latter work requires no supervision, the only condition being that the coolies had to keep a sufficient number of pits ready in advance for boring. Wherever I asked men to work on this system they readily consented and the return of work was ample for the money spent.

45. Under the above system the cost of borings, in all classes of soil except hard rock, taken by me has ranged from 3 annas to 8 annas per foot depending on local conditions. Boring in hard rock is generally given at from Rs. 5 to Rs. 10 a foot. These, however, do not

take into account cases of accident the cost in which case is hard to estimate. One who gets through the work of deep boring without accidents deserves to be congratulated and rewarded.

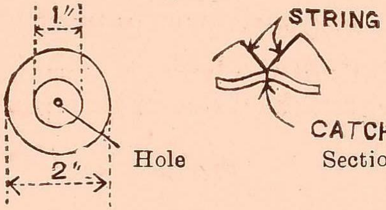
RECORD OF RESULTS.

46. A point not the least important in connection with the work described in the preceding articles is the careful observation and recording, *then and there,* of the depths from which the various kinds of soil were obtained. When lining pipes are being sunk in sand strata by working the nose shell auger, the depth from which the soil in the shell auger is obtained is that to which the pipes have sunk. To facilitate these observations being made readily and with no mistake a gauge in feet should be temporarily marked with chalk on each lining pipe as soon as it is screwed on to the one below. The number of feet should be carried up continously from the lowest pipe of the series. The depth observed should be from ground level for which purpose a string line may be stretched across the top of the pit and the point where it touches the lining pipe read off. When using clay auger, chisel and other tools, observations of the depth at which the tool worked should be made every time *before the tools are hauled up* for emptying the contents &c. Nothing should be left unrecorded on spot in which case only there is the least likelihood of mistakes occurring.

47. In addition to the soils, the water level also should be noted. A very convenient and accurate method

of sounding the water level in boreholes is to tie a lead sounder made of shape shown in figure 30 to the end of a measuring tape and sound the water level.

Fig. 30.



Plan. Section.

The water level should be observed in the morning before the work commences as it is only then that the true rest level of the subsoil water is obtained. Also the level at which the water was *tapped* in a borehole should be noted in all cases. The final rest level of water may, under sub-artesian conditions, be higher than the level at which water was tapped. (See Fig. 32.)

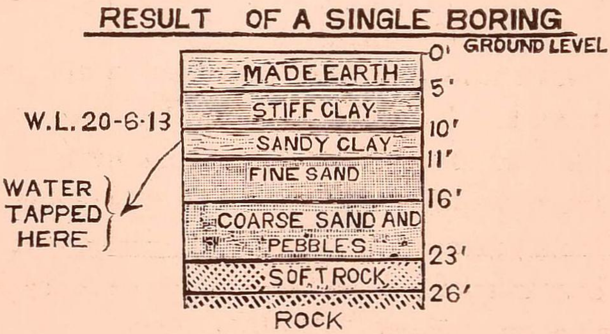
48. A very convenient pocket book to record observations made on the field is a bound one of size about 6″ × 4″ with pages ruled horizontally with one-eighth inch spaces.

SUBSOIL PLANS AND SECTIONS.

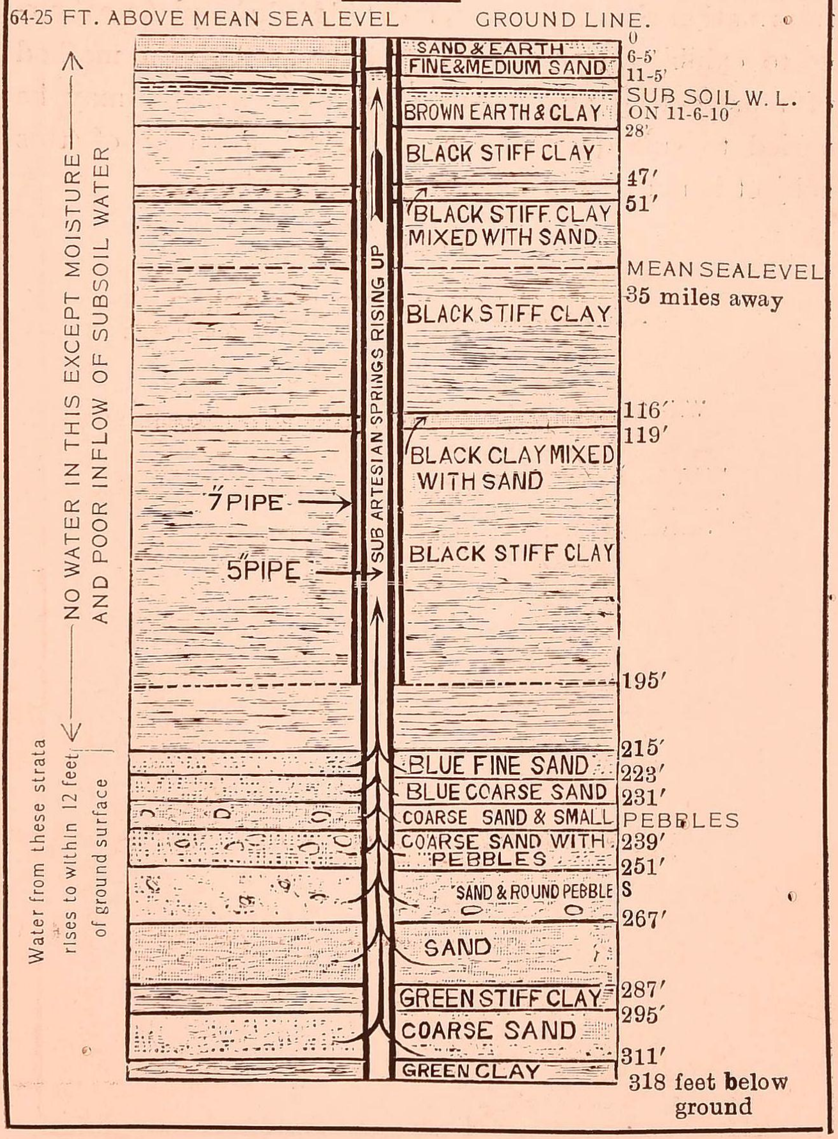
49. To present the results obtained by borings clearly to the eye, they may be plotted on plans and sections according to the requirements of each case. Figures 31 to 36 illustrate some typical cases. In the limited space available here the plans and sections are shown to a very small scale and the more important

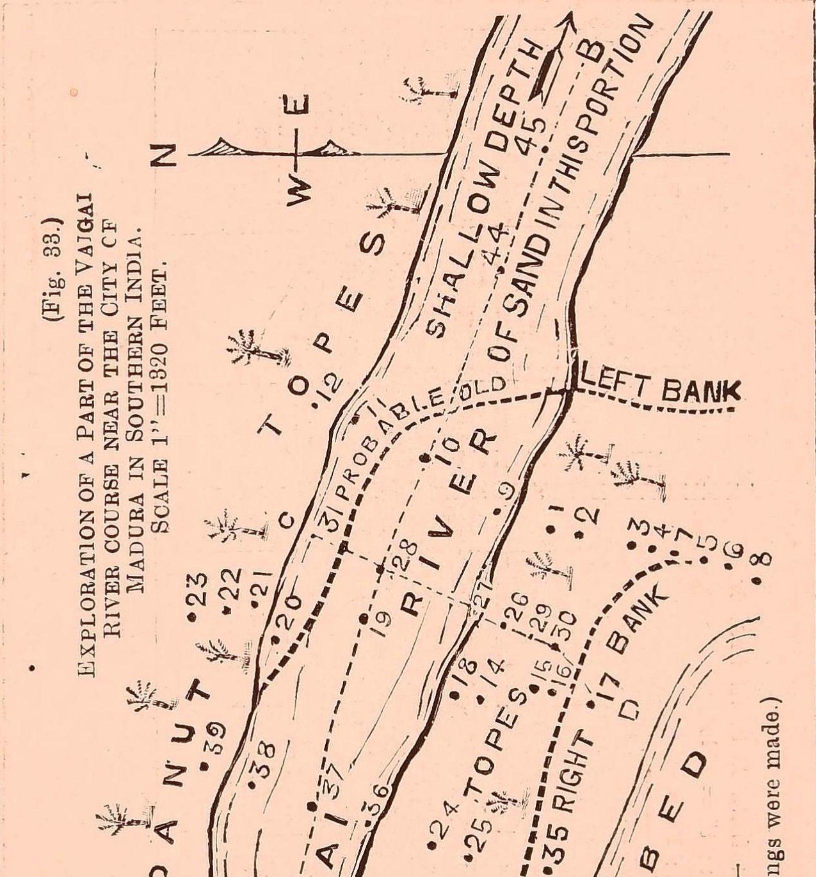
results only are marked on them. In actual practice they may preferably be drawn to a much larger scale, information shown in greater detail and the plans coloured to exhibit the results more clearly. Also the method of representing any particular result on plans may be varied to suit different cases. Further study of this subject is not within the scope of this volume.

Fig. 31.



SUB ARTESIAN BORING (FIG. 32.)
IN THE HEART OF KUMBAKONAM TOWN
SITUATED IN THE CAUVERY DELTA (SOUTHERN INDIA)





(Fig. 33.)

EXPLORATION OF A PART OF THE VAIGAI RIVER COURSE NEAR THE CITY OF MADURA IN SOUTHERN INDIA.

SCALE 1''=1320 FEET.

NOTE.—

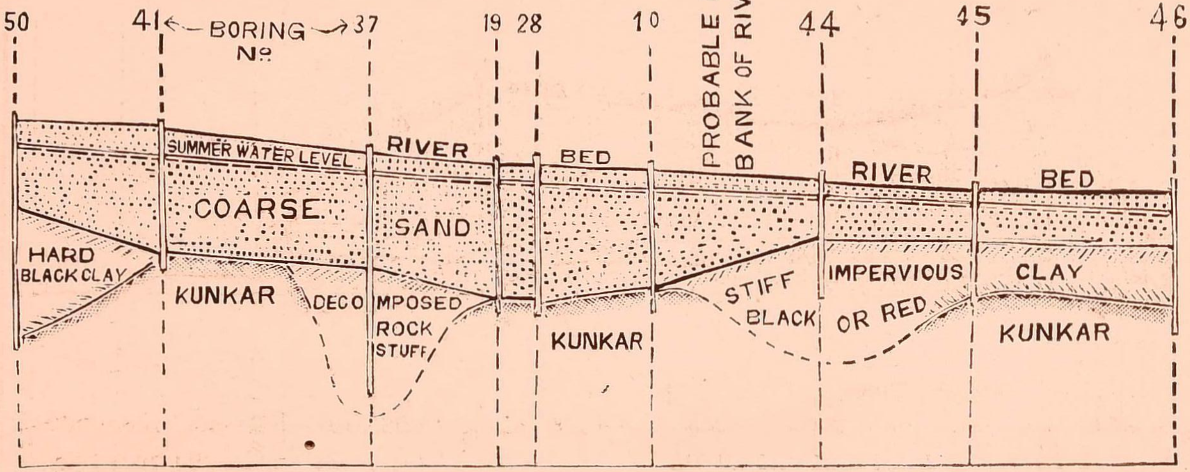
(: Are points where borings were made.)

(Fig. 34.)

Section along Line A. B. in Fig. 33.

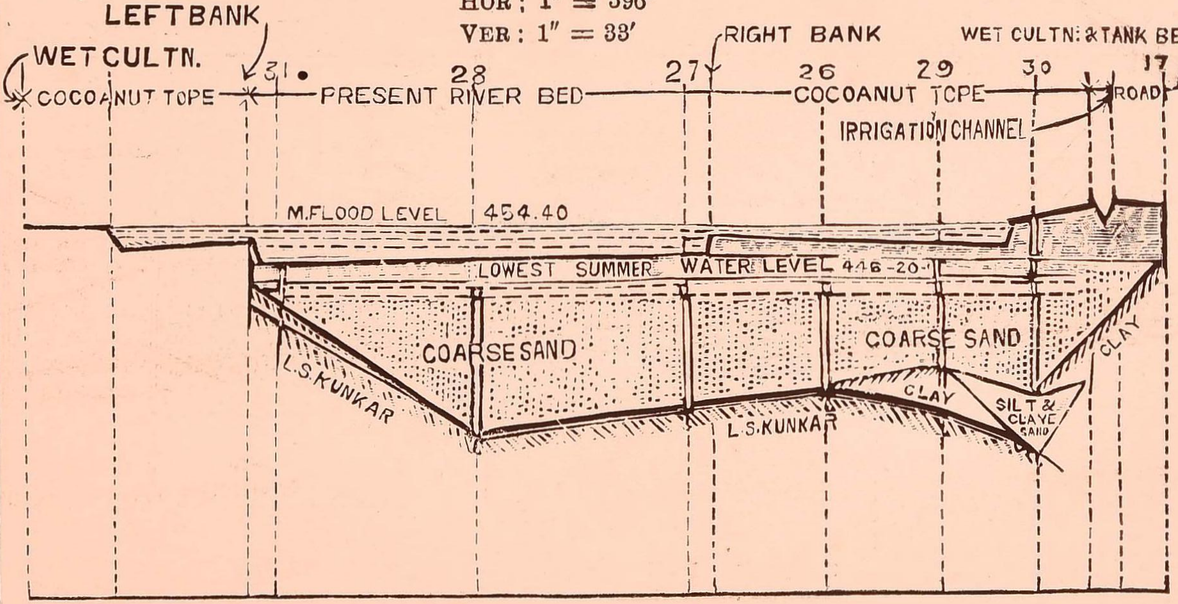
Hor : 1″ = 1320′

Ver : 1″ = 33′

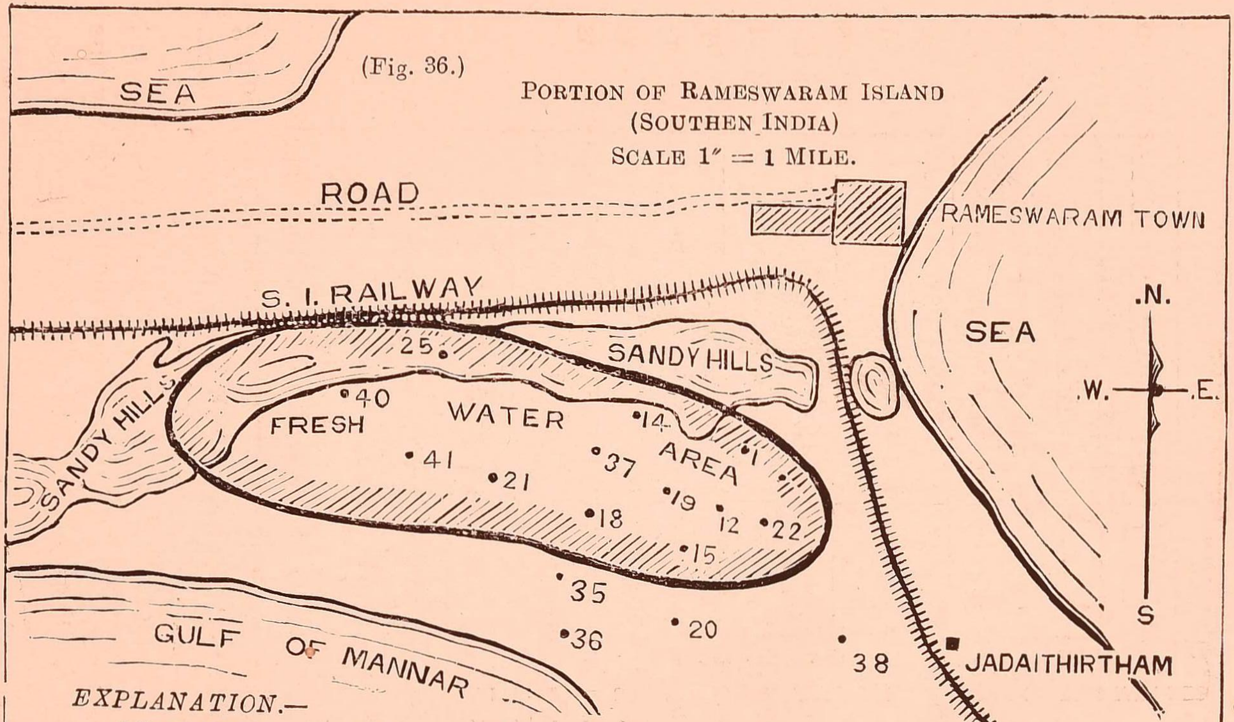


(Fig. 35.)

SECTION ALONG LINE C. D. IN FIG 32.
HOR: 1″ = 396′
VER: 1″ = 33′



(Fig. 36.)



PORTION OF RAMESWARAM ISLAND
(SOUTHEN INDIA)
SCALE 1″ = 1 MILE.

EXPLANATION.—

• SHOW POSITIONS OF BORINGS MADE.

In Search of a fresh water area it was found by borings that in the sandy area shown hatched the subsoil water is uniformly fresh to a remarkable degree to about 40 feet depth.

CONCLUSION.

50. I hope that I have introduced my readers to the subject of earth boring referring also to the various objects of the process, its advantages &c. While the methods described in this manual serve to make borings about 100 feet deep by one process the general ideas and experience gained thereby should, I daresay, enable those engaged in the work to pursue the subject further in regard to boring to greater depths and the numerous other methods of boring in practice. This can be achieved, in the first place, by diligent collection and study of literature and catalogues on the subject, and secondly by examining works in progress wherever there are opportunities. It would perhaps be useful to note the following information in regard to literature on the subject as far as I am aware of.

Bibliography.

1. Well Boring by C. Isler, cost 10sh. 6d. A standard book on the subject.

2. Swindell's Wells and Well Sinking, cost 2sh.

3. The Present Practice of Sinking and Boring Wells by Ernest Spon, cost 4sh. 6d. A very good book.

4. Practical Well Sinking by B.A. Harrison, C. E., B. Eng., price 1sh. 10d. A recent publication by the Technical Publishing Co., Ltd., 55-56 Chancery Lane, London, W. C.

5. Borehole and Borehole Machinery by J. W. Cable, A. M. I. M. E., 110 Cannon Street, London, E. C. price 2sh. A recent publication well spoken of.

*6. Improved System of Boring or Testing for Water by Pundit Matadin Sukul, M. A., Ex. Engr., P. W. D., Eastern Bengal and Assam, price 12 as. (Government publication.)

*7. Temple's Well Boring. A Government publication of the United Provinces, Price Rs. 1-4-0. Contains a description of the boring operations carried out in the Muzafferpore District during a year of drought and famine.

8. Kazusa system of Deep Well Boring for Water by F.J. Norman, Published by Messrs. Thacker Spink and Co., Calcutta and priced at Rs. 4. Notes and reports describing the boring operations as practised in Japan with local bamboo used in the process.

9. Musto's Patent spring-stroke Boring Plant made by Messrs. Richardson and Cruddas, Bombay. Descriptive pamphlet of this method of boring is issued by the firm free of cost. Several advantages are claimed for this method which was devised by Mr. Musto of the Bombay P. W. D. when he was Agricultural Engineer in that Presidency.

10. Catalogues and lists on the subject issued by Messrs. (1) Richardson and Cruddas, Bombay and Madras; (2) Burn and Co., Calcutta and Madras; (3) Oakes and Co., Madras; (4) Massey and Co., Madras; (5) Marshall Sons and Co., Ltd., Madras, &c. &c.

11. A catalogue of Earth Boring plant and tools of the Schmid's Engineering Co., 64, Mark Lane, London, E. C. A very nice catalogue containing much useful information.

12. Articles on the subject in the Encyclopaedia Britanica, Engineering Wonders of the World, and certain periodical journals and reports.

(* Publications 6 and 7 do not appear to be available now. Probably the previous editions are sold out and not reprinted.)

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Commercial Press, Madras, S. E.